Purpose/Objective(s): The aim of this study was to decide if symptomatic response to fractionated stereotactic radiation therapy (FSRT) of patients with pituitary adenoma diagnosed as acromegaly has been better than patients with Cushing disease.

Materials/Methods: Twenty-one patients with residual or recurrent pituitary adenomas after surgical and medical treatments have been treated with FSRT from April, 2010 to December, 2012. Eighteen of 21 patients treated with FSRT who were diagnosed as acromegaly (10) or Cushing disease (8) have been evaluated retrospectively. Fractionated stereotactic radiation therapy was indicated for symptoms related to persistent high hormone levels or mass effect of the adenoma. All the patients received a total dose of 21 Gy in 3 daily fractions to >95% of the planning target volume, accept 2 patients (who have been treated with radiation therapy before) with 20 Gy in 5 daily fractions. Median follow-up was 10 months (range, 3 to 31 months) after the end of FSRT. The end result was symptomatic improvement. The ratio of symptomatic improvement with FSRT in patients with acromegaly vs Cushing disease was compared with chi-square test.

Results: The median age of the study group was 44 years (range, 22 to 65 years) and female to male ratio was 1:25. Eleven of the 18 (61.1%) patients had recurrent and 7 (38.9%) had residual disease following surgery and medical treatment before SFRT. Only 2 patients have been treated initially with conventional radiation therapy (1) and gamma knife radiosurgery (1) before FSRT. Symptomatic improvement was achieved with FSRT in most of the patients with residual or recurrent pituitary adenomas (72.2%). This high ratio of symptomatic improvement was achieved both in patients with Cushing disease (71.4%) vs acromegaly (80%) after FSRT ($p = 1.0$).

Conclusions: Patients with residual or recurrent pituitary adenomas refractory to surgery and medical treatment show symptomatic improvement after FSRT. The high ratio of symptomatic improvement in patients with acromegaly is also achieved in patients with Cushing disease with FSRT.

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2159

Postoperative Stereotactic Body Radiation Therapy (SBRT) for Patients With Spinal Metastasis: Predictive and Prognostic Factors Analysis

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Purpose/Objective(s): Spine SBRT is increasingly being applied to the post-operative patient, as an alternative to conventional palliative radiation therapy, with the aim to improve upon existing rates of local control. As an emerging indication, our aim was to identify clinical and dosimetric predictors of local control and survival.

Materials/Methods: Eighty patients treated between October 2008 and February 2012 with post-operative SBRT (within 8 weeks of surgery), were identified from our prospective database and retrospectively reviewed. The pre- and post-operative MR images were reviewed to characterize the disease extent within the spinal segment, and to grade epidural disease such that grade 0 is no epidural disease, grade 1 is dural compression without spinal cord displacement, grade 2 is cord compression with visible CSF and grade 3 is cord compression obliterating CSF. Other factors analyzed included type of surgery, use of systemic therapy post-SBRT, prior radiation exposure, total dose, dose per fraction and various dosimetric factors.

Results: The median follow-up was 8.3 months. The most common primary histology was non-small cell lung cancer (16%), and 56% of tumors were in the thoracic spine. Sixty-nine (86%) patients underwent a decompressive surgery while 11 (14%) underwent a stabilization procedure alone. Thirty-five (44%) patients were treated with 1 or 2 fractions (total dose ranging from 18-26 Gy), and 45 (56%) with 3 to 5 fractions (total dose ranging from 18-40 Gy). Pre- and post-operative epidural grade 0, 1, 2, and 3 were observed in 5%/8%, 35%/82%, 35%/10%, and 25%/0% of patients, respectively. 21 local failures (26%) were observed, and the 1-year local control (LC) and overall survival (OS) rates were 84% and 64%, respectively. The median time to local failure was 6.9 months (range, 0.1 - 37.4 months). The most common site of failure was within the epidural space (15/21, 71%). We identified systemic therapy post-SBRT as the only significant predictor of OS ($p = 0.03$). Multivariate proportional hazards analysis identified treatment with1 or 2 fraction SBRT, and a post-operative epidural disease grade of 0/1 as significant predictors of LC. Subset analysis for only those patients with a pre-operative epidural disease grade of 2 or 3 (n = 48/80) indicated significantly greater LC rates when down-graded to 0/1 vs 2 ($p = 0.0009$).

Conclusions: We observed favorable local control 1 year following post-operative spine SBRT. We observed total doses ranging from 18-26 Gy delivered in 1-2 fractions, and epidural disease debulking predicted for superior local control.

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2160

A Pilot Study on Spine Stereotactic Body Radiation Therapy Residual Setup Errors and Intrafraction Motion Using Stereotactic X-ray Image Guidance Verification System

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Purpose/Objective(s): To determine the precision of our institution's current immobilization devices for spine SBRT, ultimately leading to recommendations for appropriate planning margins.

Materials/Methods: We identified 12 patients (25 treatments) with spinal metastasis treated with spine Stereotactic Body Radiation Therapy (SBRT) at the Jefferson Hospital for Neuroscience. The Body Fix system was used as the immobilization device for thoracic (T) and Lumbar (L) spine lesions. The head and shoulder mask system was used as the immobilization device for cervical (C) spine lesions. Initial patient setup used the infrared positioning system with body markers. Stereotactic X-ray imaging was then performed and correction was made if the initial setup error exceeded predetermined institutional tolerances, 1.5 mm for translation and 2° for rotation. Three additional sets of verification x-rays were obtained pre, mid, and post treatment for all treatments. The calculated residual shifts and rotations were recorded to track intrafraction motion. The translational, rotational, and 3D variances between pre-, mid-, and post-treatment imaging were calculated and used for data comparison.

Results: Intrafraction motion regardless of immobilization technique was found to be 1.28 ± 0.57 mm. We performed a comparison of the Body Fix immobilization system for T- and L- spine to the head and shoulder mask immobilization for C-spine. The mean and standard deviation of the variances along each direction were as follows: Superior-inferior, 0.56 ± 0.39 mm and 0.77 ± 0.52 mm, ($p = 0.25$); Anterior-posterior, 0.57 ± 0.43 mm and 1.14 ± 0.61 mm, ($p = 0.01$); Left-right, 0.48 ± 0.34 mm and 0.74 ± 0.40 mm, ($p = 0.09$), respectively. There was a significant difference in 3D variance of the Body Fix as compared to the head and shoulder mask immobilization system, 1.04 ± 0.46 mm and 1.71 ± 0.52 mm; ($p = 0.003$), respectively.

Conclusions: Overall, our institution's image guidance system using stereotactic X-ray imaging verification provides acceptable localization accuracy as previously defined in the literature. We observed a greater intrafraction motion for the head and shoulder mask as compared with the Body Fix immobilization system, which may be a result of greater C-spine mobility and/or the suboptimal mask immobilization. Thus, better immobilization techniques for C-spine SBRT are needed to reduce setup error and intrafraction motion. We are currently exploring alternative C-spine immobilization techniques to improve set up accuracy and decrease intrafraction motion during treatment.

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2161

Adjacent or Same Vertebral Body Retreatment With Repeat SBRT (Stereotactic Body Radiation Therapy) Is Safe Despite High Cumulative Dose to the Spinal Cord or Cauda Equina

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Purpose/Objective(s): SBRT is increasingly used to treat spinal metastases (sMet). As more patients present with recurrent metastases to the same or adjacent vertebral level following SBRT, repeat SBRT is pursued as a therapeutic option. However, this exposes regions of the spinal cord/cauda equina (SC/CE) to cumulative doses that may exceed its tolerance. The objectives of this study were to assess the clinical safety of repeat SBRT and estimate cumulative dosimetry to the overlap region.

Materials/Methods: This was a retrospective review of 23 sMet patients treated from June 2006 to January 2012. Patients underwent repeat SBRT following in-field or adjacent recurrence after initial SBRT, yielding a total of 24 overlap regions of the SC/CE (22 patients with 1 overlap and 1 patient with 2 overlaps). Forty-six CT treatment plans were generated on iPlan 4.1 (Brainlab Inc.) and imported into MIM v5.2.1 using DICOM RT format. For each patient, both plans were fused using rigid image registration to develop a voxel by voxel composite plan, and the overlap region(s) was identified and contoured. The 2 dose matrices were accumulated within MIM to generate a composite dose-volume histogram for the overlap region. Composite dosimetric endpoints included volume, maximum dose (MD), D0.035 cc, D0.1 cc, D0.35 cc, V10 Gy and V12 Gy. The time interval between initial and repeat SBRT treatments was recorded. Adverse events were evaluated based on Common Toxicity Criteria for Adverse Events v4.0.

Results: Fifteen overlap regions were located in the SC and 9 were in the CE. Median time to repeat SBRT was 7.1 mos for all patients (range, 0.2-27.4 mos) with a median time of 7.1 mos for SC (0.2-14.0 mos) and 4.9 mos for CE (1.1-27.4 mos). Mean overlap volume was 3.2 cc (1.7 cc for SC; 5.7 cc for CE) with a mean MD of 18.4 Gy (17.6 Gy for SC; 19.7 Gy for CE). The mean V10 was 47.9% (45.0% for SC; 55.2% for CE), and mean V12 was 37.6% (33.8% for SC; 47.1% for CE). No adverse events were observed in 6 patients. Grade 1 and 2 toxicities were reported in 16 patients and included fatigue, nausea, vomiting, and sensory/motor neuropathy. One patient experienced Grade 3 myelopathy (foot drop); this patient had sacral overlap with a time to retreatment of 4.9 mos and received a cumulative MD of 28.6 Gy and V12 of 53%.

Conclusions: To date, this is the largest report of repeat spine SBRT in the literature. Patient outcomes suggest that repeat SBRT at the same or adjacent vertebral level is a relatively safe therapeutic strategy. Interestingly, the overlap region of the SC/CE was subjected to a much higher V10 and V12 than current guidelines for a single course of SBRT, and a wide range of time intervals was noted between the first and second SBRT treatments. These findings support continued use of repeat SBRT for treatment of recurrent sMet.

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2162

A Dosimetric Evaluation of Target Coverage as a Predictor of Local Failure Following Stereotactic Body Radiation Therapy for Spinal Tumors

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Purpose/Objective(s): Excellent local control (LC) for spinal tumors can be achieved with highly-conformal stereotactic body radiation therapy (SBRT); however, predictors for local failure (LF) remain unclear. We present a dosimetric analysis of target volume coverage to determine factors that may lead to LF.

Materials/Methods: Sixty-seven spinal tumors were treated with SBRT at our institution between February 2008 and January 2012. Median age was 61. Tumors were malignant (n = 63) or benign (n = 4). All patients had a pre-SBRT KPS of $\geq$70. SBRT constituted re-treatment in 31% of patients (n = 21). Image-guided (Cone Beam CT) linac-based treatment was delivered with 3D-CRT (n = 4), IMRT (n = 51), or VMAT (n = 12). When available, pre-treatment MRI was fused with planning CT (n = 32). The median prescription dose (Gy) was 18 (8-35) delivered in 1-5 fractions (87% single fraction, 13% multi-fraction). Prescription dose was targeted to cover $\geq$85% of the PTV within spinal cord (SC) dose constraints (9 and 11 Gy to 0.1 cc of SC and SC+2 mm, respectively). Follow-up imaging (CT or MRI) was available for 55 tumors (82%). LC and LF were retrospectively assessed by a neuroradiologist. Twelve tumors had evidence of LF (22%) and median time to failure was 3.7 mos. These tumors were compared to LC tumors with >1 year of follow-up and complete dosimetric information (n = 15). These 27 tumors were then analyzed. The absolute volume and percent of PTV receiving < 80% of the prescription dose was assessed. Mean values are reported. Continuous variables were compared with the Mann-Whitney U test and categorical variables with chi-square.

Results: Median follow-up was 7.4 mos (range, 1.3-36.5 mos) and 24.7 mos (range, 8.4-41.4 mos) for LF and LC, respectively. No patients developed post-SBRT myelopathy. Fifty percent of LF patients had neurological symptoms due to tumor progression post-SBRT. Pre-treatment PTV volumes (cc) were similar (median, mean, and range of 61.8, 74.5, 19.9-206.4 (LF) and 39.7, 49.1, 10.3-119.7 (LC), $p = 0.24$). The absolute volume (cc) of PTV receiving < 80% of the prescription dose was significantly higher for tumors with LF, 5.2 $\pm$ 3.9 compared to 1.9 $\pm$ 2.3 for tumors with LC ($p = 0.003$). Similarly, the percentage of PTV outside the 80% isodose line was higher in the LF group (8% $\pm$ 4% v 4% $\pm$ 3%, $p = 0.01$). Maximum SC dose was similar (6.6 $\pm$ 2 Gy (LF) v 7.2 $\pm$ 3.4 Gy (LC), $p = 0.83$).

Conclusions: PTV and percent volume receiving < 80% of the prescription dose are dosimetric parameters predictive of local failure after spinal SBRT. Maximum SC doses were similar between LF and LC groups, and may reflect the need to compromise target coverage in order to respect SC constraints in the LF group. Given the absence of spinal cord toxicity but 50% symptomatic neurological progression upon LF, less conservative SC constraints should be considered to achieve better PTV coverage.

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2163

Timely Radiosurgery for Spine Metastases per RTOG 0613 Guidelines Using a Rapidly Deployable Automated Planning Script

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Purpose/Objective(s): The ongoing RTOG 0613 trial seeks to determine whether image-guided radiosurgery/SBRT (16 or 18 Gy) safely improves outcomes for spinal metastases. Practical barriers nevertheless exist to the timely treatment of urgent cases using current standards for SRS planning. We explored the use of an automated inverse planning workflow designed to minimize planning time and eliminate the need for IMRT quality assurance (QA) allowing rapid delivery of conformal single fraction spine SRS per RTOG 0613 guidelines.

Materials/Methods: Using the "FastPlan" automating script adhering to RTOG 0613 dosimetric constraints for the spinal cord was used to generate single fraction plans for fourteen complex spinal lesions previously treated at our institution. A CTV was defined according to International Consortium guidelines and the FastPlan script automated the placement of an isocenter, created a PTV (2 mm expansion excluding the thecal sac),